DDE Annual Report

Title of Investigation:

Concepts and Retrieval Analysis for an Unmanned Aerial Vehicle (UAV) Radiometer

Principal Investigator:

Gail Skofronick-Jackson (Code 975)

Other In-house Members of the Team:

Bryan Monosmith (Code 555)

Other External Collaborators:

None

Initiation Year:

FY 2004

Aggregate Amount of Funding Authorized in FY 2003 and Earlier Years:

$0

FY 2004 Authorized Funding:

$50,000

Actual or Expected Expenditure of FY 2004 Funding:

Contracts: (1) $25,000 to Richard Aldridge, CAELUM, for technician support; (2) $25,000 to University of Maryland Baltimore County/Goddard Earth Science and Technology Center (UMBC/GEST) for post-doctoral support of project

Status of Investigation at End of FY 2004:

Completed and terminated in FY 2004

Purpose of Investigation:

This study investigated the feasibility and design details of measuring rain and surface characteristics using a radiometer on an Unmanned Aerial Vehicle (UAV). As shown in Figure 1, the Stepped Frequency Microwave Radiometer (SFMR), developed by ProSensing and used operationally by NOAA to measure hurricane precipitation and surface wind speeds, is compact in size, weight, and power requirements. It is ideal for use on a UAV. In FY 2003, we purchased the ProSensing device for $130,000, and in FY 2004, we carried out our investigation, which included two objectives. The first was determining whether we could modify the SFMR to also provide sea surface temperature (SST) estimates; and second, to investigate conceptual engineering design details to place an SFMR-like instrument into the Global Hawk UAV.

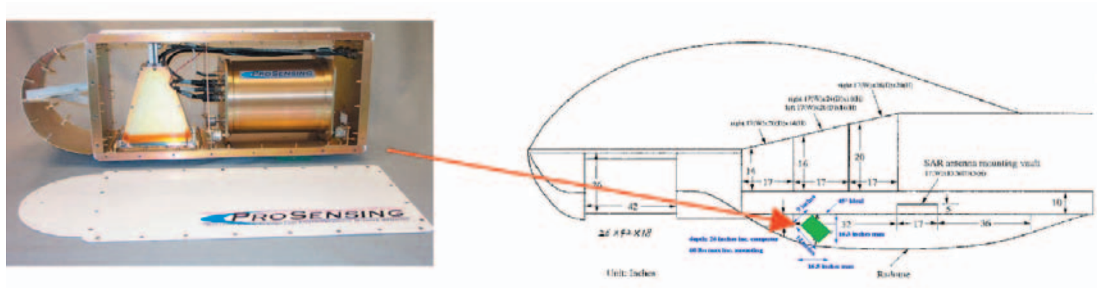

Figure 1. The ProSensing SFMR and outline of placement in Global Hawk UAV. The radiometer is 20 x 14 x 9", 40 lbs., and requires 2 Amps.

FY 2004 Accomplishments:

We performed a conceptual and theoretical retrieval analysis to determine if the SFMR could be modified to determine SST. We found that the SFMR frequency band (4.5 to 7.2 GHz) does respond to SST through changes in the ocean surface emissivity. However, the wind speed also is positively correlated with ocean surface emissivity at the nadir-viewed linear polarization of the off-the-shelf SFMR. Radiative transfer calculations for various configurations and cloud and surface conditions provided the brightness temperatures used in this analysis. The analysis showed that pointing the SFMR at about 45° off nadir provides a weak but measurable sensitivity to SST.

Figure 2 indicates the sensitivity of the SFMR to rain rate (a) and wind speed (b). Using these plots (and similar ones for various channel combinations), the SFMR data can be used to determine first surface rain rate and then surface wind speed. The SFMR performance has already noted difficulties determining low rain rates and Figure 2a shows the convergence of brightness temperature value lines for low rain rates. Once the rain rate and wind speed have been noted, Figure 3 shows that there is an approximate 3 Kelvin slope sensitivity for a 6°C SST change when the SFMR is pointed at a 45° incidence angle with respect to nadir. This means that there is a 0.5 Kelvin sensitivity to SST. Given the known SFMR accuracy and precision, the theoretical analysis shows that we would be able to estimate increases and decreases of 0.2K in SST, but not necessarily the actual values of the SST. If the SFMR or UAV aircraft included a simple infrared (IR) sensor, then the SST could be "calibrated" to an exact value in clear air regions where the IR could see all the way to the ocean surface.

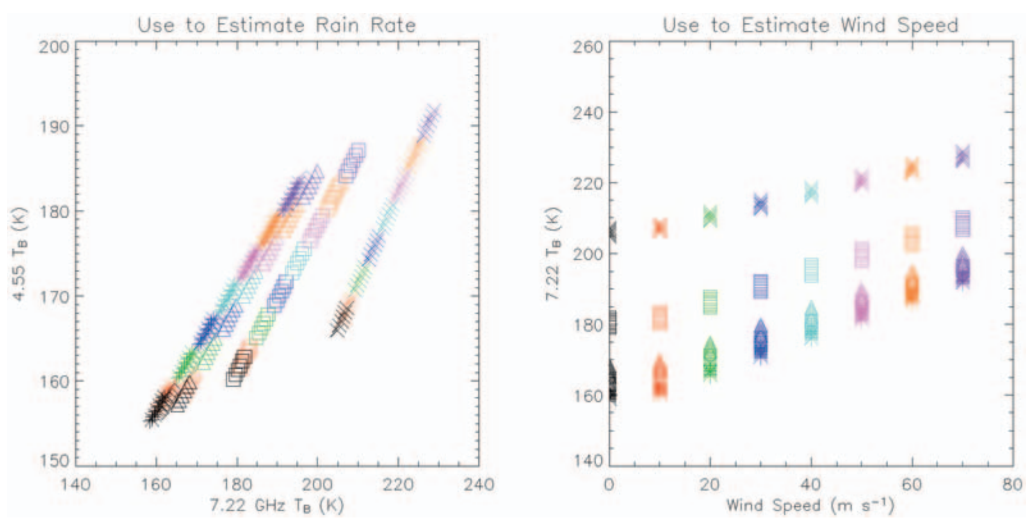

Figure 2. (a) Plot to estimate rain rate (b) plot to estimate wind speed. Other similar plots are available to confirm these retrievals.

The Global Hawk UAV was targeted as a viable aircraft due to coordination with other instruments (e.g., lidar, radar, and dropsonde pods). Unfortunately, despite the apparent interest at NASA Headquarters in UAVs, funding to purchase and support instrument development for this radiometer lidar and radar was not provided in FY 2004, nor does it appear forthcoming in FY

2005. This proposed investigation was only for SST analysis and for thermal and mechanical engineering design. Thus, this project was considered terminated in FY 2004. However, if additional UAV funding becomes available, a modified SFMR would make an ideal and complementary instrument for UAV hurricane and oceanic studies.

This work was written up as a science highlight report for Code 970 in March 2004. In addition, a journal paper entitled, “Measuring Sea Surface Temperature using the Stepped Frequency Microwave Radiometer” by G. Skofronick-Jackson and H. Jiang is being prepared for *IEEE Geoscience and Remote Sensing Letters*.

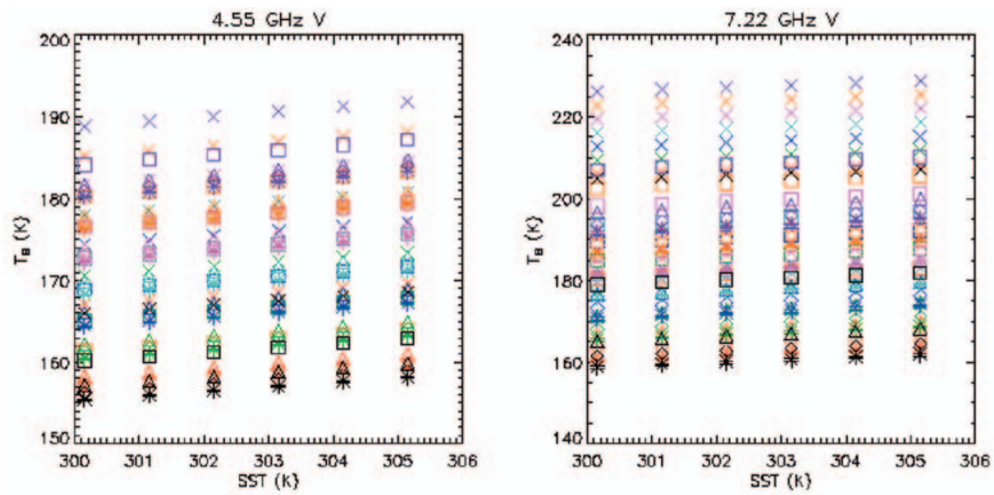

Figure 3. Given a retrieved wind speed and rain rate as provided by the operational SFMR, there is an approximate 3 Kelvin slope sensitivity to a 6°C SST change.

Planned Future Work:

If additional funding for the purchase of the SFMR becomes available and there is a call for a UAV mission/field campaign, this work will be continued.

Summary:

The project’s innovative features included a commercial-off-the-shelf instrument used for an innovative application — measuring SST from UAVs. The capability would give the Goddard Space Flight Center the first use of UAV radiometer instrumentation and complementary and extensive observations of SST, wind speed, and rain rate over ocean surfaces. Showing that the SFMR was a viable instrument for SST, rain rate, and wind speed from a UAV was the criterion for success. We showed this computationally. The technical risk factors included sensitivity to SST given the small frequency range and desire for a low-cost instrument.